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A DYNAMIC COMPUTER MODEL FOR
SIMULATING MILITARY COMMAND
SYSTEMS

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A Dynamic Computer Model for Simulating Military Command Systems

This paper describes a computer-based, war-gaming model that operates under a time-sharing system on a large scale digital computer. The model simulates a command system comprised of a command post and a network of subordinate weapon control centers, weapon launch platforms, weapons, sensors, and their interconnecting communication links. Its major purpose is to serve as a general simulation tool that can be readily adapted to simulate a variety of command systems and conflict situations. As such, it can aid in the evaluation of performance and effectiveness of command-control systems, operating as vulnerable networks in dynamic conflict with a reactive enemy.

The model, which received final testing in the Command Research Laboratory at SDC in November, 1964, provides:

- a mock-up of a command post in the Laboratory, with teletype links between the command staff and the forces simulated in the computer,
- teletype links between the command post and simulated sensors,
- manually updated displays, upon which current operational data are plotted,
- computer programs to simulate an enemy who commits weapons in response to game events (both programmed events and dynamic actions taken by the command staff),
- computer programs to simulate the dynamic processes of a war, such as flight of weapons, destruction of resources, delays and outages in communications, and failure of weapons.

The model's programs are highly parameterized, so they can be adapted conveniently to simulate many different types of military systems and conflict situations. It operates in either of two basic modes: (1) as an algorithmic model in which its programs run as a closed system within the computer; and (2) as an open simulation, in which humans in the command post interact "on-line" with the program system. The humans monitor the simulated conflict situations as reported by the modeled sensors and weapon control centers, make special requests for information, and issue orders to commit weapons or to change their level of readiness.

The model was developed under ARPA contract SD-97 as a simulation vehicle to support a command-control research program being conducted at SDC. The functional design was completed in December 1963 by a team of analysts headed by R. M. Longmire. The programming of the model for the computer was completed in August 1964 under the direction of C. A. Kribs. R. G. Archambault was responsible for the development of operating procedures in the laboratory.

The first version of the model occupied the 47,000 words of core memory available to object programs under the time-sharing system of the Q-32 computer. Modifications to this version have been completed to enable the use of the disc, in addition to the core memory, for data and program storage. With this change, the model can simulate a command-control system operating with realistic numbers of weapons, targets, sensors, and communication facilities.

General Description of the Modeled System

The military entities included in the model are command posts, weapon control centers, weapon platforms, weapons, communication links, sensors, and passive targets. As shown in Figure 1, these entities form a hierarchical organization that operates as a complete command-control system during the simulated conflict.

The following paragraphs summarize briefly the functions and performance parameters of these entities as modeled in the simulation system:

- Command Post. In the open simulation mode (includes human operators working on-line), the command post is simulated in the Laboratory, where command staff personnel analyze incoming messages that pertain to the status of their own forces and the observed actions of the enemy, and prepare "estimates of the combat situation." The person acting as the Commander issues orders to change the alert status of weapons and to launch attacks, either in response to orders from higher headquarters or on the basis of the situation and his doctrine of tactical operations. Personnel in the command post also perform damage assessment analyses and formulate plans for subsequent attacks.

  Variations in the performance of the command post can be introduced by changing the size of the staff, the location of the staff members with respect to the Commander and each other, the types of messages each staff member receives, the available data processing and display aids, the doctrinal relationship with higher level commands, and the time delays in receiving messages and transmitting orders to the subordinate weapon control centers.

  The command post for the enemy system is modeled by an adaptive scenario--a computer program that models several attack plans and includes a logic for switching from one plan to another as the conflict proceeds. Each attack plan contains a time schedule for sending orders to change the alert level of specified weapons and

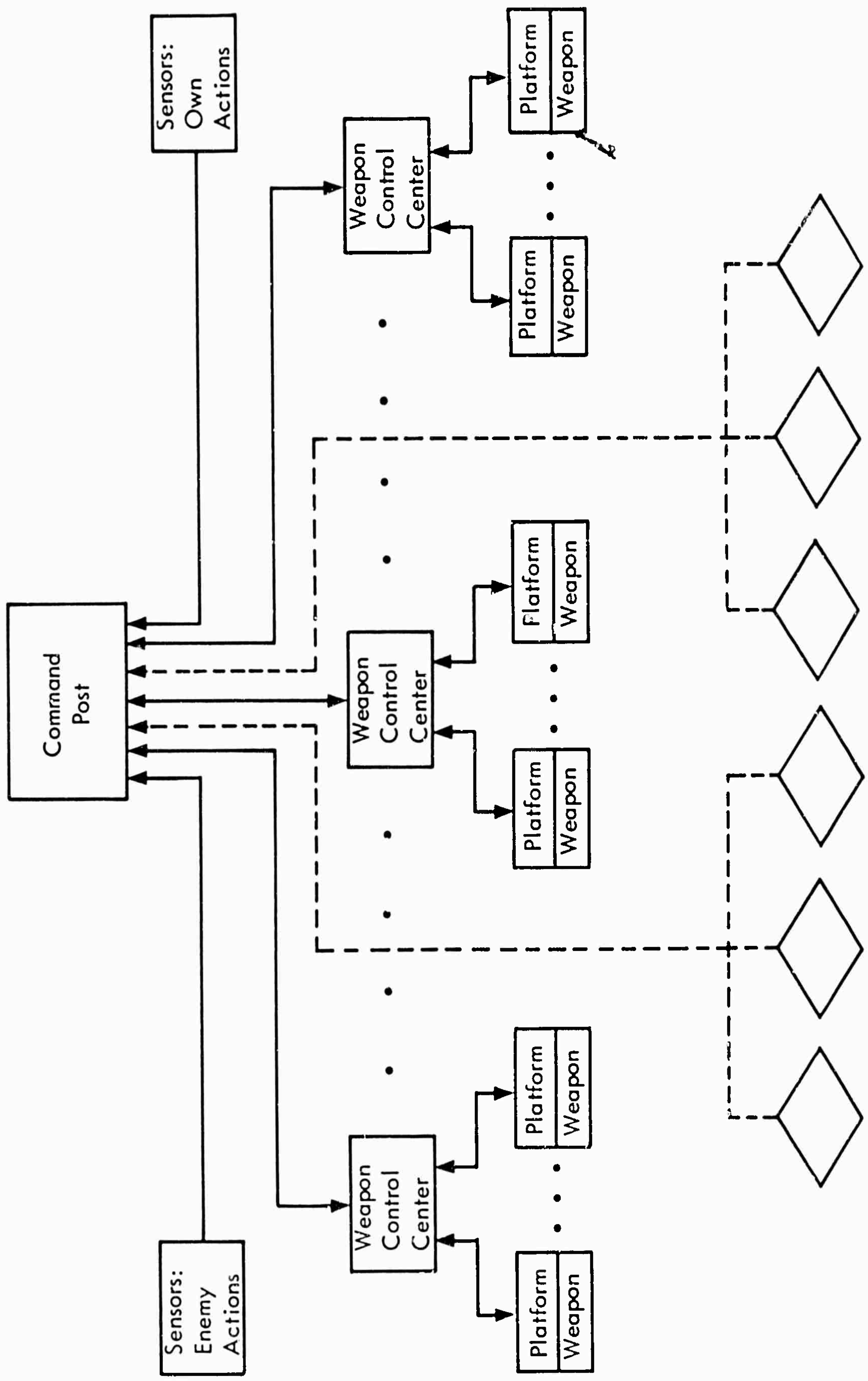

Figure 1. Modeled Command Organization

to fire them against specified targets. The logic for switching plans during the course of a simulated conflict depends upon threshold parameters that describe the relative size of the attacks by both sides, the number and type of targets under attack, the relative timing of attack and counter-attack, and the size of the remaining forces on both sides.

- Weapon Control Centers. The weapon control centers receive orders from the command posts and check to see if there is adequate time to carry them out. If an order can be carried out, the message is routed to the appropriate weapon platform; if not, a report is sent back to the command post, stating that the order is infeasible.

  The weapon control center is either fixed in location or mobile; if it is mobile, its position is changed through time to correspond to a pre-planned course. The program parameters set for a weapon control center are location, future locations versus time if the control center is mobile, vulnerability (hardness), number and identity of weapon platforms under its control, and the length of time required to process and transmit messages to upper and lower echelons in the command system.

- Weapon Platforms. The weapon platforms receive orders from the weapon control centers and check them for feasibility. If the weapon has not already been destroyed or launched, and time limits in the order have not been exceeded, the order is carried out; that is, the state of alert is changed or the weapon is fired. If the order can not be carried out, an infeasibility report is generated and sent back through the weapon control center to the command post.

  Parametric characteristics of the weapon platforms are location, future locations versus time if the platform is mobile, vulnerability, and the time required to change the alert status of the weapons.

- Weapons. The weapons in the model are the units of force under the control of the command system for use in actions against a similar enemy system. The weapons, when fired, move through space and time to the impact point. At the time of impact, damage is calculated, and the appropriate changes are made to the characteristics of the targets affected by the impact.

  The parameters that determine weapon performance are the length of time it can be held on alert, the probability of abort during the initial phase of flight, the probability that it will fail to penetrate to the target during the terminal phase of flight, the inflight velocity, the circular error probable (CEP) for the impact location with respect to the target, and the power of the warhead (yield).

- Sensors. The sensors generate reports that are transmitted to the command post to inform the command staff of observed enemy actions and observed results of its own attacks. The events that can be detected by the sensors are the firing of enemy weapons, enemy weapons in flight, and impact by weapons on both sides. Also, messages can be generated and sent to the command post to report the post-launch aborts and the failure of its own weapons to penetrate to the target.

  The performance of a sensor is described in terms of the events observed, the error distribution for observed events, the probability of detection, probability of false alarms, the area of coverage, the location and vulnerability of the sensor and the time required to process and transmit data to the command post.

- Communications. Communications circuits provide means for transmitting messages among the entities in the command system. A circuit is defined by its two end points and the intervening nodes (or critical points in the circuit).

  Each circuit is described in terms of the location and vulnerability of the end points and intervening nodes, the mean time to failure, the mean time to repair, and the capacity (the number of messages that can be transmitted per unit of time). A circuit will not function if it is temporarily closed for repair or if an end point or an intervening node has been destroyed by enemy action.

- Passive Targets. Passive targets are included to represent all facilities that are not part of the operating command system, but whose destruction can be the object of an attack. The list of passive targets includes cities, weapon storage sites, administrative centers, etc. Each such target is described in terms of its location, vulnerability, and value (utility) to the command system.

Computer Programs Constituting the Model

To accommodate requirements for convenient and rapid modification of the modeled situation and for economical operation in real or "fast" time under the time-sharing system, the computer programs for the model have been organized as shown in Figure 2. In the Figure, three types of programs and two types of data storage comprise the operating system; they are: (1) the control program, (2) the functional modules, (3) the input, output, and recording programs, (4) the data base, and (5) buffer storage.

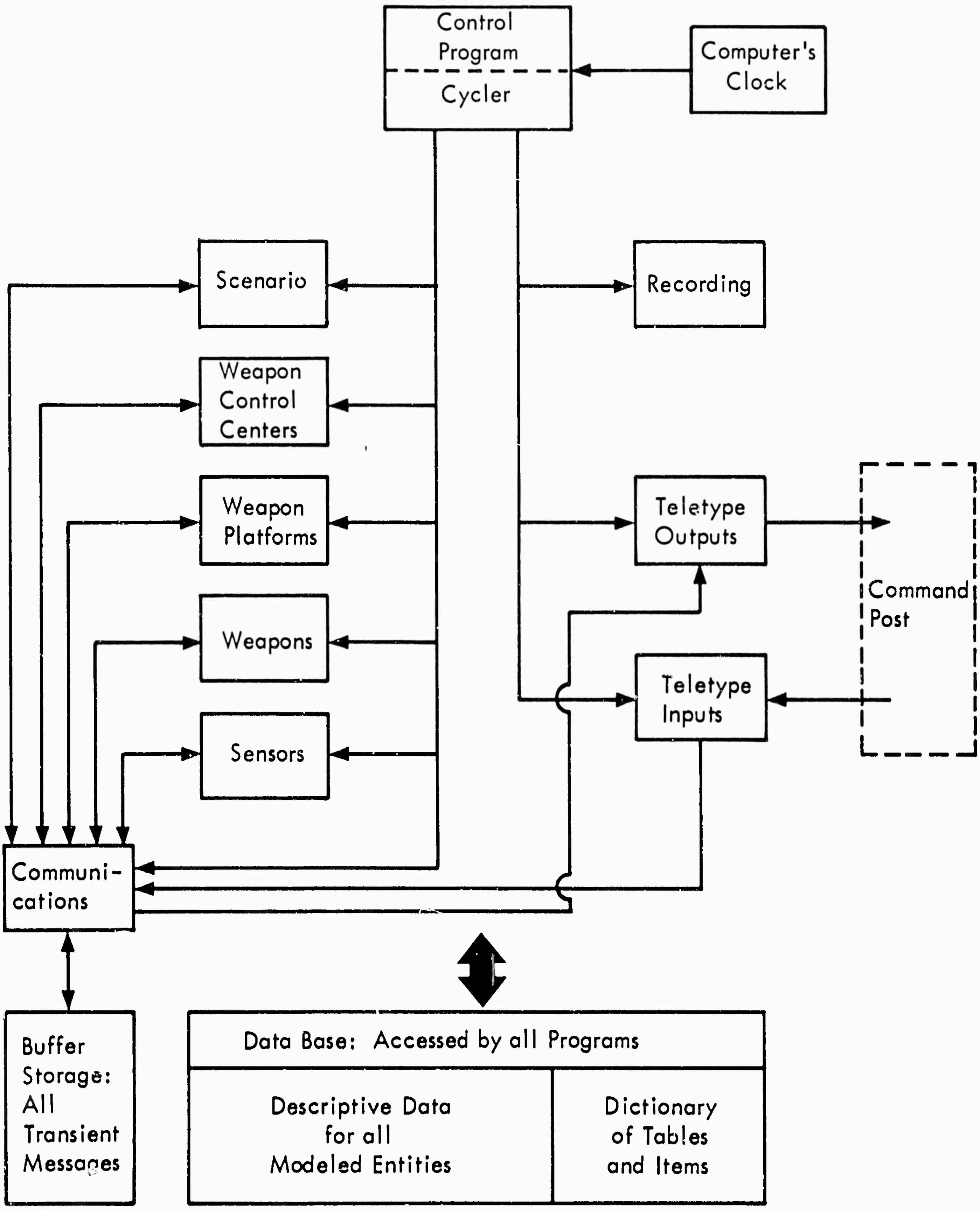

Figure 2. Organization of Model Programs

The control program contains the cycler that controls the sequence for operating the functional modules and the input-output programs. During a simulation run, the cycler checks each functional module and input-output program in turn to see if it is ready to operate. If, as a result of this check, the cycler finds that operation of a particular functional module is required, the cycler allows the module to initiate and complete the necessary computations, and then it resumes control. For example, if an order to fire a weapon has just been received by the weapon platform module, it will be ready to operate (i.e. "fire" the weapon) when it is next checked by the cycler. If the module is not ready to operate (e.g. no "firing" orders received), it is bypassed and checked again during the next "cycle." The cycler operates some of the functional modules on a periodic basis, that is, every Δt minutes, where Δt is a parameter. An example is the functional module that "moves" the weapons through space.

The functional modules simulate the operations of the modeled entities that were described in the previous section of this paper. When a functional module is directed by the cycler to operate, it determines which actions are to be taken with specific entities in the model. It then accesses the data base for performance characteristics and operational data, and performs its functions.

All messages that flow between functional modules in the system are sent through the communications module, where appropriate delays are introduced. The communications module stores the messages in temporary buffer storage and sends them on after the appropriate time delay has passed, but only if the communication link is operating.

The teletype input program is the means by which humans enter orders into the operating system for the functional modules. Teletype messages are routed to the communications module and are then handled in the same way as other messages in the system. The teletype output program receives messages from the communication module and routes them to the appropriate output channel in the command post. If the program system is operating as a closed model, the input-output programs are not used for processing operational messages. In this case, all orders to the forces are generated by the adaptive scenario (simulated command posts).

The recording program operates under control of the cycler throughout the simulation run. It records the contents of data base tables and message-storage buffers as specified prior to the run. Data are recorded on either a periodic basis or whenever changes are made in the tables or buffers of interest.

The data base is comprised of fixed-length, parallel tables that contain the descriptive data for each modeled entity and a dictionary defining all tables and items in the data base. During a simulation run, each program in the system accesses appropriate subsets of the descriptive data to carry out its functions. The dictionary is used primarily by the input-output programs and the executive of the time-sharing system.

The buffer storage contains only transient information, that is, data that are generated, used, then destroyed during the course of a simulation run. All messages, reports, and orders are considered as transient information and hence are stored in the buffer. Associative lists are used for buffer storage instead of fixed-length tables because of the variations in the amount of transient information during a run.

Operating Characteristics of the Computer Program System

The procedure for configuring the model's program system and for operating it under time-sharing are related as shown schematically in Figure 3. The preparation of the functional programs for operations on the computer is independent of the data base on which the system operates. The functional programs, which have been coded in the time-sharing version of JOVIAL (JTS), are compiled under time-sharing on the Q-32 computer. The data base is prepared and loaded onto tape with a utility program (Data Base Load). The data base is called in by the model's control program when the system is ready to run on the computer. This separation of the programs and the data base contribute greatly to the model's flexibility and ease of use because major changes can be made to the data base, i.e., the situation being simulated without disturbing the rest of the program system.

When the model is to be used for open simulation studies, operational plans are prepared for use by the staff in the command post and stored "off-line" on a symbolic tape. As shown in Figure 3, the preparation of these plans is also independent of the functional programs and the data base, so that revised and new plans can be introduced easily.

When a desired configuration of the system has been obtained and stored on the disc (or tape initially) for repeated use, minor changes to both the programs and the data base can be made easily by using the Debug program of the time-sharing system.

During operations under time-sharing, the model's programs are handled in the same way as other object programs in the system. The programs are read into core initially from disc or tapes and then swapped on and off the drums as they are called to operate by the time-sharing executive.

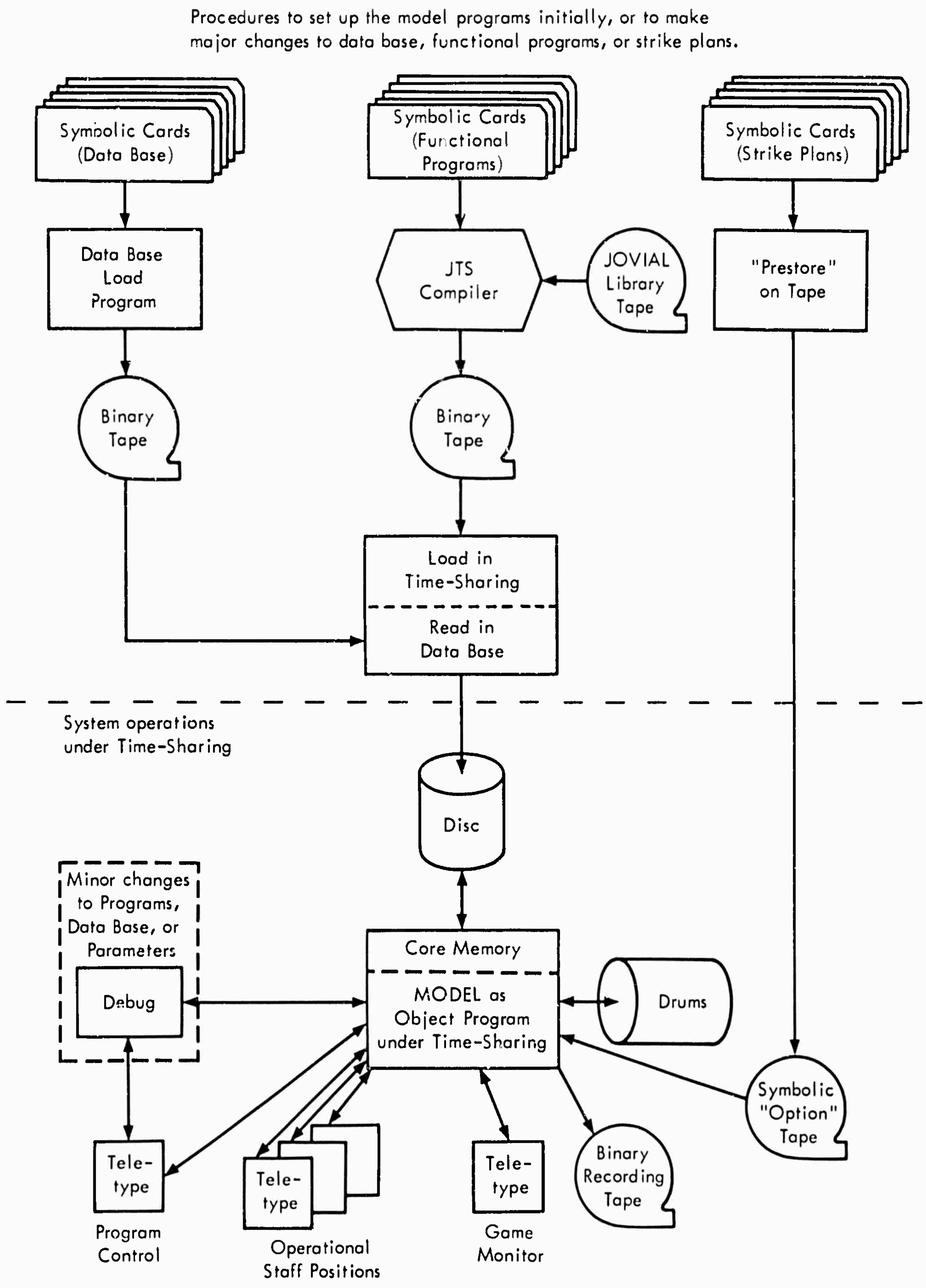

Figure 3. Initialization and Operation of Computer Programs

The command staff performs its functions during open simulation runs in a mock-up of a command post in the Laboratory (see Figure 4). The "on-line" teletypes provide the means by which all communications between the command post personnel and the modeled command system (computer programs) take place. During a simulation exercise, the Commander has the responsibility for maintaining the state of readiness of all forces in his command and for committing them to carry out strike plans. All orders to alert, de-alert and launch weapons are input from the Commander's position. The Commander can execute a strike plan by inputting a single message to call the plan from the "option" tape and thereby generate individual orders to all the forces.

The Intelligence Staff provides the Commander with estimates of the status of the enemy forces and the damage done to the enemy. It receives sensor reports on observed enemy actions and copies of all incoming reports pertaining to actions taken against the enemy. The Operations Staff maintains records on the status of all forces under the Commander's control and estimates the damage sustained during enemy attacks. It receives sensor reports on the results of enemy actions and other reports from their own forces which help in evaluating the success of their strikes.

The Game Monitor teletype receives noise-free output data, reporting on the enemy actions and the "true" results (error-free) of all attacks. The experimenters at this position act as the umpires during the war game. They also simulate other command organizations that interface with the command post. Communications among all personnel participating in the exercise is accomplished with either telephones or teletypes.

Personnel at the Program Control position set up the program system and monitor its operations throughout the game. All data that are output on the teletypes, plus those recorded on tape, provide the basis for post-simulation analysis of results. The binary information recorded on tape during a run is processed by another utility program (Data List). This program produces a time-ordered listing of the data selected by the user for post-simulation analysis.

Conclusion

This war gaming model was developed primarily to simulate military systems operating during a general nuclear war. However, because of the emphasis placed upon flexibility and modularity in the design of its computer programs, the model can also be used to study many different types of military systems operating in a variety of tactical situations.

In general, the model is suitable for studies of systems comprised of several echelons of command and control in which performance depends upon timely flow of information throughout the system. That is, decisions to commit forces are made on the basis of an incoming stream of data that may contain errors,

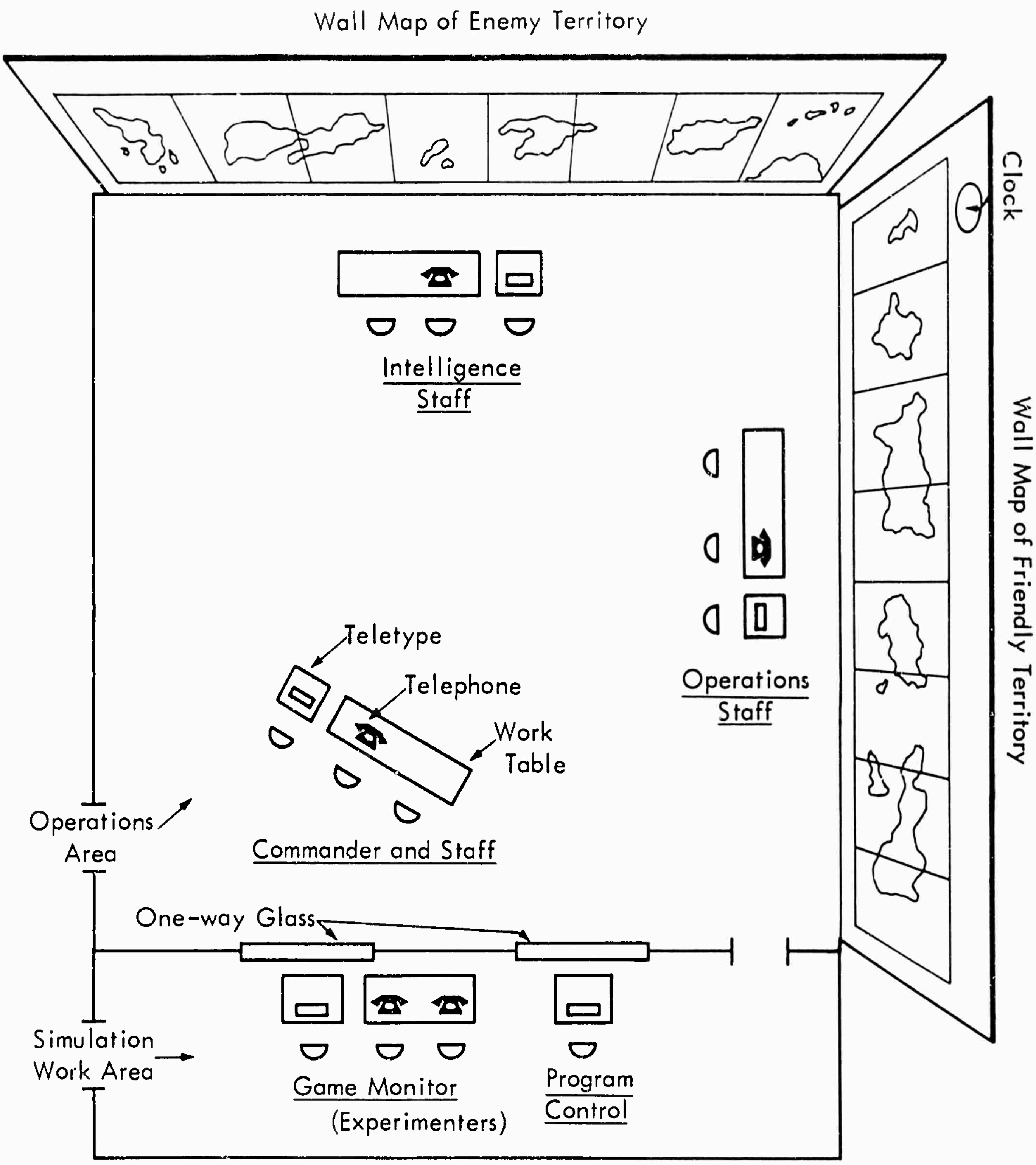

Figure 4. Layout of Laboratory Command Post

redundancy, time delays, and may be incomplete. The success of the ordered actions depends on the speed with which they can be carried out as well as the correctness of the estimate of the situation and the adequacy of the strike plan.

In addition to its use as a tool for systems analysis, several military observers have suggested that the model has considerable potential as a training and exercising vehicle for military personnel, but that for such use some modifications would be required. This observation illustrates rather well the principal characteristic of the model: since it is general-purpose, it will usually require some modifications before it can be used for most specific applications. In many cases, changes will be required only in the data base. But even if changes to the programs are required, the cost of modifications will be very slight compared to the cost of developing a special purpose model to serve the same purpose. With this capability, the model has become a valuable addition to the software tools available to users of the Q-32 computer in the study of command-control systems.

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13. ABSTRACT

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